Sensory Attributes, Phytotoxicity, and Production of Grape Cultivars after Treatment with Two Deer Repellents

Larry D. Howery,[1]
Dale L. Nolte,[2]
Lawrence M. Sullivan,[3] and
Michael W. Kilby[4]

Additional index words. deer, pest management, vineyards, wildlife damage, wine, *Vitis vinifera*

Summary. The objective of our experiment was to determine if the application of two deer repellents to six grape cultivars (*Vitis vinifera* L.) caused significant phytotoxic effects, production losses, or altered the sensory characteristics of wine. We evaluated fifteen single vine plants from six different cultivars in a randomized block design that included the two repellent treatments and an untreated control. During spring 1997, we applied repellents biweekly from budbreak until flowering (2 Apr. to 14 May). Plantskyyd was applied more frequently than recommended by the product label (for trees) due to rapid emergence of unprotected shoot growth in vineyards. Hot Sauce and Plantskydd caused some initial minor phytotoxicity during 1997, however, the yield and phytotoxicity of treated plants were similar to controls by harvest. A panel detected a significant difference in the color, aroma, or taste of 'Chardonnay' wine made from grapes treated with repellents compared to wine made from untreated control grapes ($P = 0.001$ for Hot Sauce; $P = 0.05$ for Plantskydd). We conclude that Hot Sauce and Plantskydd did not cause serious production losses or phytotoxic effects for the six cultivars treated. However, both Hot Sauce and Plantskydd significantly altered the sensory attributes of Chardonnay wine, which may preclude the use of chemical repellents in wine grape vineyards under the experimental conditions applied in our study.

Browsing damage by deer (*Odocoileus* sp.) is well documented on numerous crop species in various U.S. locations [e.g., Gill, 1992; Conover and Kania, 1995 (Connecticut); Beringer et al., 1994 (Missouri); Nolte et al., 1995 (Pacific Northwest)]. Deer depredation in southeastern Arizona vineyards varies from year to year. Deer losses are usually most severe when winter and spring precipitation is insufficient to support native forage growth in surrounding areas. Vineyards and other irrigated agricultural crops apparently provide an attractive food source for deer during drought conditions. For instance, deer browsing during spring 1996 (a very dry year) was estimated to reduce grape production by about half in a commercial vineyard in southeastern Arizona (A. Buhl, personal communication). Deer damage in 1996 was observed to be greatest when vines were rapidly growing (April to May) but lessened after flowering (around the end of May). In contrast, deer damage was inconsequential during the 1997 and 1998 growing seasons when rainfall was slightly above average. Other vineyard managers in southeastern Arizona have reported similar trends in deer depredation.

Fencing vineyards and other cash crops with deer-proof material is effective but expensive (Craven and Hygnstrom, 1994), and given the apparent intermittent and short-term need for protection against deer damage in Arizona vineyards, there may be cheaper alternatives. Scare devices (e.g., propane exploders, balloons, flashing lights) may initially be effective but animals habituate to them fairly quickly (Craven and Hygnstrom, 1994). Lethal control may require special permits from game agencies, may not be socially acceptable to some individuals and groups, and is seldom a practicable long-term solution. Chemical repellents may provide a viable means to diminish periodic browsing episodes in Arizona vineyards, however, before repellents can be applied operationally, the potential consequences on vineyard productivity must be known.

The objective of our study was to test whether application of Miller's Hot Sauce (Miller Chemical and Fertilizer Corp., Hanover, Pa.) or Plantskydd (Tree World, Sechelt, B.C.) to six grape cultivars caused significant phytotoxic effects, production losses, or altered sensory characteristics (i.e., color, aroma, or taste) of 'Chardonnay' wine. We chose Hot Sauce and Plantskydd because these products have been demonstrated to deter deer browsing on evergreen tree and shrub species (Andelt et al., 1991; Nolte, 1998), however, the efficacy and potential deleterious effects on grapevine productivity have not been evaluated.

Materials and methods

Our study was conducted in southeastern Arizona in the Dos Cabezas Wine Works vineyard. The cultivars included in our study were 'Cabernet Sauvignon', 'Chardonnay', 'Petite Sirah', 'Sauvignon Blanc', 'Syrah', and 'White Reisling'. The 'Chardonnay' and 'Syrah' were 3 years old, and the other four cultivars were 10 years old. We chose these six cultivars because they were selectively and severely damaged by deer in previous years.

The study was a randomized block design that included five replications located within a single row of each cultivar. Three treatments (i.e., Hot Sauce, Plantskydd, and an untreated control) were randomly assigned to three plants within each block. To create a

We thank Al Buhl and associates for permitting this research in the Dos Cabezas Wine Works Vineyard, Willcox, Ariz. We acknowledge Miller Chemical and Fertilizer Corporation, Hanover, Pa., for donating Hot Sauce, and Tree World, Sechelt, British Columbia for donating Plantskydd. We thank J. Russell Mason, Dennis T. Ray, and two anonymous reviewers for reviewing earlier drafts of this manuscript. Their comments and suggestions greatly improved our paper. We acknowledge Robert Steidl for statistical advice. Mention of trademark, propriety product, or vendor does not constitute a guarantee or warranty of the product by The University of Arizona or USDA-APHIS and does not imply its approval to the exclusion of other products or vendors that may also be suitable. The cost of publishing this paper was defrayed in part by payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]The University of Arizona, School of Renewable Natural Resources, Biological Sciences East 325, Tucson, Ariz. 85721. To whom reprint requests should be addressed.

[2]USDA-APHIS, Animal Damage Control, Denver Wildlife Research Center, 9701 Blomberg Street, Olympia, Wash. 98512.

[3]The University of Arizona, School of Renewable Natural Resources, Biological Sciences East 325, Tucson, Ariz. 85721.

[4]The University of Arizona, Plant Sciences Department, Forbes 439, Tucson, Ariz. 85721.

buffer between treatments and blocks, at least one plant was left untreated between treatments and at least five plants were left untreated between blocks.

We applied repellents to the entire plant with hand sprayers once every 2 weeks from 2 Apr. to 14 May (four times total) because this was when deer damage was most severe in previous years. Frequency of application (i.e., biweekly) was higher than recommended by Plantskydd for conifers (i.e., every 3 to 4 months), but considered necessary due to rapid emergence of unprotected shoot growth. Hot Sauce was applied at the highest recommended label concentration of 100× [8 fl oz/gal (62.51 $mL \cdot L^{-1}$)]. Plantskydd was applied at the recommended label concentration [200 $g \cdot L^{-1}$ (24.33 oz/gal)]. Shoot length was measured every two weeks from 2 Apr. to 28 May (five times total). Phytotoxicity was ranked 1 to 5 (1 = severe phytotoxicity, i.e., leaves and stems showed severe yellowing, burning, or necrosis; 5 = no phytotoxicity) once every two weeks from 16 Apr. to 28 May, in August 1997 just before harvest, and a final time on 1 July 1998 to determine if there was any carryover phytotoxicity from repellent application in 1997.

Soluble solids were measured with a hand-held model refractometer (ATAGO ATC-1, Automatic Temperature Compensation, Brix Range 0% to 32%; Kernco Instruments Co., Inc., El Paso, Texas). At harvest, the total number of clusters per vine were counted and hand harvested, then weighed. 'Cabernet Sauvignon' was not harvested due to logistical problems which did not permit collection of cluster and weight data for that cultivar.

We used analysis of variance to determine potential effects of repellents on initial and final phytotoxicity and production during 1997. In the initial test, repellent treatments, grape cultivars, and repellent application dates were factors in a repeated measures design. In the final test, repellent treatments and grape cultivars were factors in a factorial design. We also used analysis of variance to evaluate the final phytoxicity rankings taken 1 July 1998, ≈13.5 months after the final repellent application in 1997.

To determine if repellent application adversely affected the sensory characteristics of the 'Chardonnay', we sorted grapes by treatment which were made into wine by the Dos Cabezas wine maker. On 27 May 1998, a triangle test as described by Meilgaard et al. (1991) was conducted at the University of Arizona's Agriculture Center, Tucson. A sensory panel consisting of 12 individuals compared the color, aroma, and taste of wine made from the two repellent treatments and the untreated control (Meilgaard et al., 1991).

Results and discussion

INITIAL PHYTOTOXICITY AND PRODUCTIVITY TESTS. During the period when repellents were applied (2 Apr. to 14 May), we detected yellowing and curling of leaves (i.e., phytotoxicity) on plants treated with Hot Sauce and Plantskydd (Fig. 1). Our statistical analyses detected a significant date × treatment interaction for both phytotoxicity rank ($P < 0.001$; F statistic to determine differences among treatment means) = 7.1820; 8 df (treatment or numerator), 64 df (error or denominator) and shoot growth ($P = 0.0466$; F = 2.0968; 8, 74 df). The date × cultivar interaction was also significant for phytotoxicity rank ($P = 0.0005$; F = 2.7; 20, 107 df) and shoot growth ($P < 0.0001$; F = 7.5; 20, 124 df).

The date × cultivar interaction for shoot growth was expected because 3-year-old ('Chardonnay' and 'Syrah') and 10-year-old plants ('Cabernet Sauvignon', 'Petite Sirah', 'Sauvignon Blanc', and 'White Reisling') grew at inherently different rates (Fig. 2). The date × treatment interactions for phytotoxicity rank (Fig. 1) and shoot growth (Fig. 3) suggest that phytotoxicity may have retarded shoot growth slightly when repellents were applied. However, repellent-treated plants may have compensated for minor phytotoxicity by rapidly producing new phytomass. For example, we observed that yellow and curled leaves (i.e., phytotoxic effects) observed during a previous sampling date were usually covered by a new canopy of green leaves and stems just 2 weeks later. Moreover, in August, just before grape harvest, phytotoxicity ranks of repellent-treated plants were similar to controls

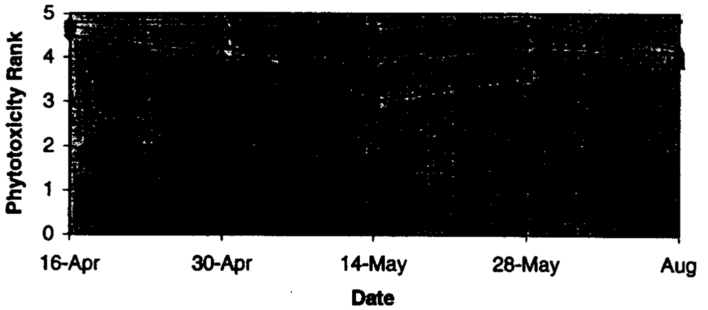

Fig. 1. Least square mean phytotoxicity rank (1 to 5) from April to August 1997, for grape cultivars treated with Hot Sauce, Plantskydd, or controls in the Dos Cabezas Vineyard, southeastern Arizona. 1 = severe phytotoxicity, i.e., leaves and stems showed severe yellowing, burning, or necrosis; 5 = no phytotoxicity, i.e., leaves and stems had no evidence of phytotoxicity.

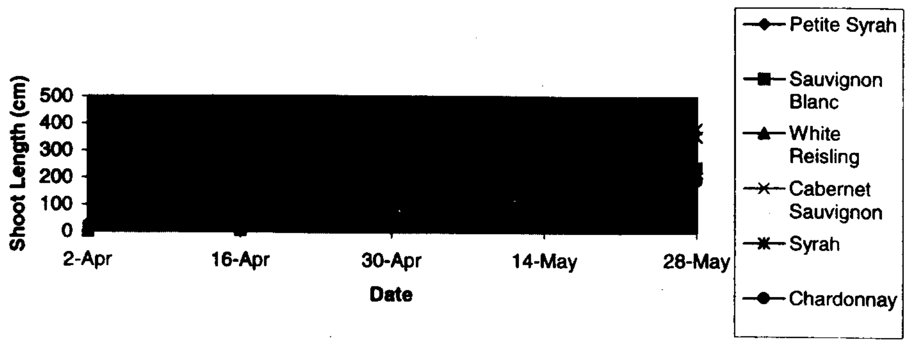

Fig. 2. Least square mean shoot growth (cm) from April to May 1997, for six grape cultivars in the Dos Cabezas Vineyard, southeastern Arizona (2.54 cm = 1 inch).

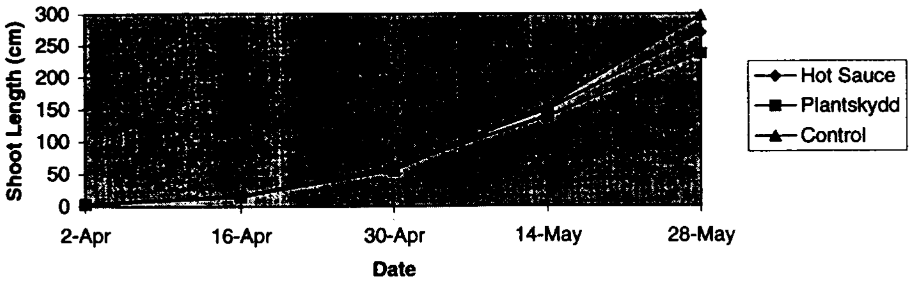

Fig. 3. Least square mean shoot growth (cm) from April to May 1997, for grape cultivars treated with Hot Sauce, Plantskydd, or controls in the Dos Cabezas Vineyard, southeastern Arizona (2.54 cm = 1 inch).

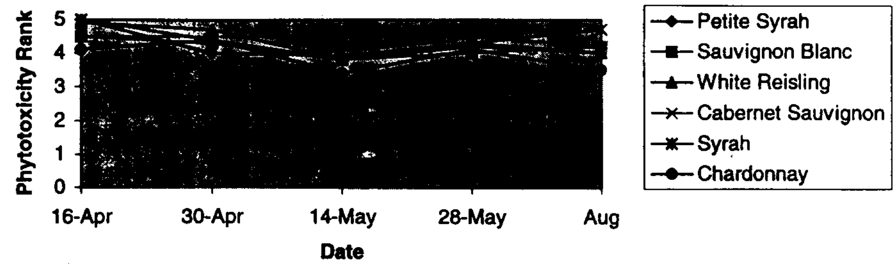

Fig. 4. Least square mean phytotoxicity rank (1 to 5) from April to August 1997, for six grape cultivars in the Dos Cabezas Vineyard, southeastern Arizona. 1 = severe phytotoxicity, i.e., leaves and stems showed severe yellowing, burning, or necrosis; 5 = no phytotoxicity, i.e., leaves and stems had no evidence of phytotoxicity.

(Fig. 1, see also next section). There was no apparent trend for any one cultivar to be more adversely affected by repellents than others (Fig. 4).

FINAL PHYTOTOXICITY, PRODUCTIVITY, AND SENSORY TESTS. Hot Sauce and Plantskydd had little or no significant impact on final phytotoxicity rank or productivity of the treated cultivars (Table 1). Neither treatment main effect nor any of its two-way ($P \geq 0.1961$) or three-way ($P \geq 0.5488$) interactions were significant for berry yield, percent solid solubles, or phytotoxicity rank. Main treatment effects for each dependent variable were as follows (Table 1): berry weight ($P = 0.0935$; F = 3.2150; 2, 30 df), cluster weight ($P = 0.1337$; F = 2.5984; 2, 30 df), cluster number ($P = 0.2340$; F = 1.7441; 2, 30 df), percent solid solubles ($P = 0.0756$; F = 3.6146; 2, 39 df), phytotoxicity rank ($P = 0.2040$; F = 1.9504; 2, 39 df). Hence, plants treated with repellents apparently tolerated and possibly compensated for minor early season phytotoxicity. Moreover, there was no difference ($P \geq 0.1927$; F = 1.4545; 10, 40 df) in phytoxicity rankings made 1 July 1998 for repellent treatment or any of its interactions (mean = 5 for Hot Sauce, Plantskydd, and the untreated control). This finding indicates there was no carryover phytotoxicity from 1997 to 1998 due to repellent applications.

The cultivar main effect was significant ($P \leq 0.0353$) for every productivity measure except cluster weight ($P = 0.1283$; F = 2.0927; 4, 30 df). We expected inherently different yield and percent solid solubles among cultivars of different ages and stages of development. However, there was also a significant cultivar × block interaction for weight ($P = 0.0340$; F = 2.1532; 16, 30 df) and number of clusters ($P = 0.0481$; F = 2.0106; 16, 30 df). The reason for this interaction is unknown but may have been due to blocks in some cultivars inadvertently receiving more irrigation than others which could have influenced grape production. For instance, we occasionally observed pools of water around some individual plants that apparently came from leaky irrigation lines.

The sensory evaluation panel detected a significant difference in the color, aroma, or taste of 'Chardonnay' wine made from repellent-treated grapes and wine made from control grapes ($P = 0.001$ for Hot Sauce, i.e., 10 of 12 individuals correctly identified the odd sample; and $P = 0.05$ for Plantskydd, i.e., 8 of 12 individuals correctly identified the "odd" sample). Under our experimental methodology (i.e., biweekly applications), treated plants may have translocated the repellents into their berries which was detected by the sensory evaluation panel in the wine samples.

Conclusions

Deer depredation in southeastern Arizona vineyards is infrequent but can be substantial when it occurs. Our

Table 1. Least square means (±SE) for berry weight, cluster number, weight per cluster, soluble solids, and final phytotoxicity ranking (1 to 5) for five or six vineyard cultivars[z] treated with Hot Sauce, Plantskydd, or controls, August to September 1997.

Treatment[y]	Berry wt (kg[w])	Cluster no.	Wt per cluster (kg)	Soluble solids[x] (%)	Final phytotoxicity ranking[v]
Hot Sauce	5 ± 0.7	73 ± 5	0.07 ± 0.005	24 ± 0.3	4 ± 0.15
Plantskydd	6 ± 0.7	87 ± 6	0.07 ± 0.005	24 ± 0.3	4 ± 0.15
Control	7 ± 0.7	85 ± 6	0.08 ± 0.005	25 ± 0.3	4 ± 0.15

[z]Cultivars were 'Cabernet Sauvignon, 'Chardonnay', 'Petite Sirah', 'Sauvignon Blanc', 'Syrah', and 'White Reisling'. Cluster and weight data were not collected for 'Cabernet Sauvignon'.
[y]Treatment main effects ($P \geq 0.0756$) and all interactions associated with treatment were not significant ($P \geq 0.1961$) for all response variables.
[x]Soluble solids were measured for all cultivars 3 Sept. 1997 except 'Chardonnay' (measured 15 Aug. 1997).
[w]1 kg = 2.2 lb.
[v]Phytotoxicity was ranked from 1 to 5 (1 = severe phytotoxicity, i.e., leaves and stems showed severe yellowing, burning, or necrosis; 5 = no phytotoxicity, i.e., leaves and stems had no evidence of phytotoxicity).

study was designed to determine if Hot Sauce and Plantskydd might be used as nonlethal alternatives in vineyards without causing significant phytotoxic effects, production losses, or altering of the sensory characteristics of wine. Both repellents caused some initial minor phytotoxicity and slightly reduced shoot growth of the six cultivars studied. By harvest however, neither Hot Sauce nor Plantskydd reduced final productivity or induced significant phytotoxic effects (Table 1, Fig. 3). Furthermore, there was no carryover phytoxicity from 1997 to 1998 due to deer repellents. Unfortunately, sensory attributes (i.e., color, aroma, or taste) of the 'Chardonnay' wine were significantly altered by both repellents as applied in our experiment (i.e., biweekly applications). Because sensory attributes are essentially a wine grape grower's bottom line, this finding may preclude the use of chemical repellents in vineyards to deter deer herbivory under the experimental conditions used in our study.

Literature cited

Andelt, W.F., K.P. Burnham, and J.A. Manning. 1991. Relative effectiveness of repellents for reducing mule deer damage. J. Wildlife Mgt. 55(2):341–347.

Beringer, J., L.P. Hansen, R.A. Heinan, and N.F. Geissman. 1994. Use of dogs to reduce damage by deer to a white pine plantation. Wildlife Soc. Bul. 22:627–632.

Conover, M.R. and G.S. Kania. 1995. Annual variation in white-tailed deer damage in commercial nurseries. Agr. Ecosystems Environ. 55:213–217.

Craven, S.R. and S.E. Hygnstrom. 1994. Deer, p. 25–40. In: S.E. Hygnstrom, R.M. Timm, and G.E. Larsen (eds.). Prevention and control of wildlife damage. Univ. Nebraska, Lincoln.

Gill, R.M.A. 1992. A review of damage by mammals in north temperate forests 1. Deer For. 65:145–169.

Meilgaard, M., G.V. Civille, and B.T. Carr. 1991. Sensory evaluation techniques. 2nd ed. CRC Press. Boca Raton, Fla.

Nolte, D.L. 1998. Efficacy of selected repellents to deter deer browsing of conifer seedlings. Intl. Biodeterioration Biodegradation 42:101–107.

Nolte, D.L., J.P. Farley, and S. Holbrook. 1995. Effectiveness of BGR-P and garlic in inhibiting browsing of western red cedar by black-tailed deer. Tree Planters' Notes 46:(1):4–6.

Comparison of Container Placement Patterns for Maximizing Greenhouse Space Use

Elizabeth Will,[1] James E. Faust,[1] and Benali B. Burgoa[2]

ADDITIONAL INDEX WORDS. efficiency, bench dimensions, staggered spacing, square spacing

SUMMARY. A series of equations were developed to provide a convenient means to calculate the number of containers that can be placed into a specified area using three different placement patterns. The calculations require three pieces of information; the container spacing, i.e., distance between the center of one container and the center of the neighboring container, and the length and width of the greenhouse bench or floor area. The solutions allow comparisons of the total number of containers that will fit into that area using three different placement patterns: square, long-staggered, and short-staggered. In general, the closer the container spacing or the larger the production area, the greater the benefit of staggered spacing compared to square spacing. Staggered spacing frequently allows for up to 13% more containers to fit into a given area than square spacing; however, calculations must be made for specific situations to determine the most efficient spacing pattern. Cost analyses were performed on a range of container spacings and greenhouse dimensions. Spacing pattern can affect overhead costs from $0.02 to $0.20 per container for a 10-week crop. A spreadsheet, Bench Crop Calculator, is available from the authors for providing assistance in performing the calculations.

The cost of publishing this paper was defrayed in part by payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]Department of Ornamental Horticulture and Landscape Design, The University of Tennessee, Knoxville, TN 37901.

[2]CDM Federal, Oak Ridge, TN 37830.

Overhead costs (including equipment, taxes, and utilities) are a significant part of total greenhouse crop-production costs. The overhead cost per square foot per week of bench space has been estimated to be $0.20 (Brumfield, 1995). Since overhead costs remain constant in a given location regardless of the crop or the number of containers produced, the efficiency with which growing space is used in order to minimize overhead costs per plant is important.

Efficient use of greenhouse space requires knowing how many plants will fit on a bench or floor so that each plant has sufficient space to grow. Containers are spaced by commercial growers on square or staggered spacing. Square spacing is frequently employed since this method is considerably easier for workers to perform accurately. Also, growers usually assume square spacing when planning for the number of containers that will fit in a greenhouse, since the calculation is relatively simple.

We are unaware of an available process through which growers can determine how to place containers on a bench or floor in such a way that the space is used most efficiently. The objective of this project was to develop a decision-support tool to calculate the maximum number of containers that can be placed in a specified area. The equations could be entered in a spreadsheet to allow growers to determine the most efficient spacing pattern for their individual situations or a spreadsheet, named Bench Space Calculator, is available from the authors.

Materials and methods

There are three commonly used patterns of container placement (Fig. 1). Square placement involves placing containers in parallel rows perpendicular to each other in both directions on the growing surface so that any four containers form a square. The other two patterns involve placing containers in staggered arrangements in which any three containers form an equilateral triangle. In the long-staggered pattern, the rows of containers are parallel to the long dimension of the bench or floor space. In the short-staggered pattern, the rows of containers are parallel to the short dimension of the bench or floor space.

We developed a series of equations to calculate the number of containers fitting in a given area in each of the three